MP101E

M-660 Rotation Stage

User Manual

Version: 1.4.0 Date: 12.02.2014

This document describes the following products:

- **M-660.45**
  PILine® Precision Rotation Stage,
  Ø 108 mm, 360°, 4 µrad Resolution
- **M-660.45V**
  PILine® Precision Rotation Stage,
  Ø 108 mm, 360°, 4 µrad Resolution,
  Vacuum Compatible to 10^{-6} hPa
- **M-660.55**
  PILine® Rotation Stage, Ø 108 mm, 360º,
  34 µrad Resolution
- **M-660.55V**
  PILine® Rotation Stage, Ø 108 mm, 360º,
  34 µrad Resolution, Vacuum Compatible to
  10^{-6} hPa

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Europe: EP0789937B1 EP1210759B1, EP1267425B1, EP1581992B1, EP1656705B1, EP1747594B1, EP1812975B1, EP1861740B1, EP1915787B2, EP1938397B1, EP2095441B1, EP2130236B1, EP2153476B1, EP2164120B1, EP2258004B1, EP2608286A2

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Subject to change without notice. This manual is superseded by any new release. The latest release is available for download (p. 3) on our website.

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1 About this Document

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1.1 Goal and Target Audience of this User Manual

This manual contains information on the intended use of the M-660.

It assumes that the reader has a fundamental understanding of basic servo systems as well as motion control concepts and applicable safety procedures.

The latest versions of the user manuals are available for download (p. 3) on our website.

1.2 Symbols and Typographic Conventions

The following symbols and typographic conventions are used in this user manual:

CAUTION

Dangerous situation

If not avoided, the dangerous situation will result in minor injury.

➢ Actions to take to avoid the situation.

NOTICE

Dangerous situation

If not avoided, the dangerous situation will result in damage to the equipment.

➢ Actions to take to avoid the situation.

INFORMATION

Information for easier handling, tricks, tips, etc.

Symbol/Label	Meaning
1. 2.	Action consisting of several steps whose sequential order must be observed
➢	Action consisting of one or several steps whose sequential order is irrelevant
▪	List item
p. 5	Cross-reference to page 5
RS-232	Labeling of an operating element on the product (example: socket of the RS-232 interface)
	Warning sign on the product which refers to detailed information in this manual.

1.3 Definition

Term	Explanation
Load capacity	Maximum load capacity in the vertical direction when the rotation stage is mounted horizontally. The contact point of the load is in the center of the platform.
Rotary encoder	The rotary encoder is an incremental sensor for capturing changes in position. Signals from the sensor are used for axis position feedback. After switching on the controller a reference point definition must be performed before absolute target positions can be commanded and reached.

1.4 Figures

For better understandability, the colors, proportions and degree of detail in illustrations can deviate from the actual circumstances. Photographic illustrations may also differ and must not be seen as guaranteed properties.

1.5 Other Applicable Documents

The devices and software tools which are mentioned in this documentation are described in their own manuals.

Description	Document
C-867.160 PILine® controller	MS185E User Manual
C-867.260 PILine® controller	MS189E User Manual
C-867.OE PILine® controller	MS195E User Manual
PIMikroMove	SM148E Software Manual
PILine® stages	MP121EK Short Instructions

1.6 Downloading Manuals

INFORMATION

If a manual is missing on our website or if there are problems in downloading:

➢ Contact our customer service department (p. 39).

The current versions of the manuals are found on our website. For some products (e.g. Hexapod systems and electronics that are delivered with a CD), access to the manuals is password-protected. The password is stored on the CD.

Download freely accessible manuals

1. Open the website **http://www.pi-portal.ws**.
2. Click ***Downloads***.
3. Click the corresponding category (e.g. ***M Hexapods / Micropositioning***)
4. Click the corresponding product code (e.g. ***M-660***).
5. Click ***Documents***.

   The available manuals are displayed.
6. Click the desired manual and save it on the hard disk of your PC or on a data storage medium.

Download password-protected manuals

1. Carry out steps 1 to 5 of the download process for freely accessible manuals.
2. Insert the product CD in the PC drive.
3. Switch to the ***Manuals*** directory on the CD.
4. In the ***Manuals*** directory, open the Release News (file including ***releasenews*** in the file name).
5. Find the user name and password in the ***User login for software download*** section in the Release News.
6. In the ***User login*** area on the left margin in the website, enter the user name and the password in the corresponding fields.
7. Click ***Login***.

   The available manuals are displayed.
8. Click the desired manual and save it on the hard disk of your PC or on a data storage medium.

2 Safety

In this Chapter

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2.1 Intended Use

The M-660 is a laboratory device as defined by DIN EN 61010-1. It is intended to be used in interior spaces and in an environment which is free of dirt, oil and lubricants.

In accordance with its design and realization, the M-660 is intended for positioning, adjusting and rotation of loads in a rotational axis at different velocities in interval operation. The M-660 is **not** intended for applications in areas in which a failure would present severe risks to human beings or the environment.

The intended use of the M-660 is only possible when completely mounted and connected.

The M-660 uses PILine® ultrasonic piezomotors as a drive and must be operated with a suitable controller (p. 12). The controller is not included in the scope of delivery of the M-660.

2.2 General Safety Instructions

The M-660 is built according to state-of-the-art technology and recognized safety standards. Improper use can result in personal injury and/or damage to the M-660.

- Only use the M-660 for its intended purpose, and only use it if it is in a good working order.
- Read the user manual.
- Immediately eliminate any faults and malfunctions that are likely to affect safety.

The operator is responsible for the correct installation and operation of the M-660.

Piezomotors are driven by piezo actuators. After being disconnected from the electronics, piezo actuators can stay electrically charged for several hours. Temperature changes can also induce charges in piezo actuators. Touching charged parts of the M-660 can cause slight injuries from electric shock.

- Do **not** open the M-660.
- Do **not** touch the contacts in the connector of the M-660.

If a protective earth conductor is not or not properly connected, dangerous touch voltages can occur on the M-660 in the case of malfunction or failure of the system. If touch voltages exist, touching the M-660 can result in minor injuries from electric shock.

- Connect the M-660 to a protective earth conductor (p. 19) before start-up.
- Do **not** remove the protective earth conductor during operation.
- If the protective earth conductor has to be removed temporarily (e. g. in the case of modifications), reconnect the M-660 to the protective earth conductor before starting it up again.

Mechanical forces can damage or misalign the M-660.

- Avoid impacts that affect the M-660.
- Do **not** drop the M-660.
- Do **not** exceed the maximum permissible stress and load capacities according to the specifications (p. 41).

2.3 Organizational Measures

User manual

- Always keep this user manual available by the M-660.
  The latest versions of the user manuals are available for download (p. 3) on our website.
- Add all information given by the manufacturer to the user manual, for example supplements or Technical Notes.
- If you pass the M-660 on to other users, also turn over this user manual as well as other relevant information provided by the manufacturer.
- Only use the device on the basis of the complete user manual. Missing information due to an incomplete user manual can result in minor injury and property damage.
- Only install and operate the M-660 after having read and understood this user manual.

Personnel qualification

The M-660 may only be installed, started up, operated, maintained and cleaned by authorized and appropriately qualified personnel.

3 Product Description

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Product Labeling 10
Scope of Delivery 12
Suitable Controllers 12
Accessories 13
Technical Features 13

3.1 Model Overview

The M-660 is available in the following versions:

Model	Description
M-660.45	PILine® precision rotation stage, Ø 108 mm, 360°, 4 µrad resolution
M-660.45V	PILine® precision rotation stage, Ø 108 mm, 360°, 4 µrad resolution, vacuum compatible to 10^{-6} hPa
M-660.55	PILine® rotation stage, Ø 108 mm, 360º, 34 µrad resolution
M-660.55V	PILine® rotation stage, Ø 108 mm, 360º, 34 µrad resolution, vacuum compatible to 10^{-6} hPa

3.2 Product View

Figure 1: M-660 product view

1 Moving platform
2 Base body
3 Cable for connecting to the controller

The arrow in the figure shows the positive direction of motion.

3.3 Product Labeling

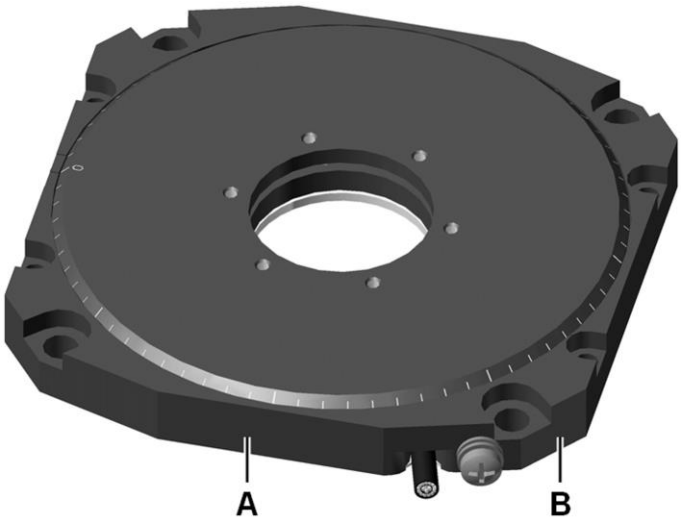

Figure 2: M-660: Position of the product labeling (example view)

Position	Labeling	Description
A	PI	Manufacturer's logo
A	CE	CE conformity mark
A	⚠	Warning sign "Observe manual!"
A	M-660.45	Product name (example), the places after the point refer to the model
A	113064246	Serial number (example), individual for each M-660 Meaning of the places (counting from left): 1 = internal information 2 and 3 = manufacturing year 4 to 9 = consecutive numbers
A	WWW.PI.WS	Manufacturer's address (website)
A		Data matrix code (example; contains the serial number)
A		Old equipment disposal (p. 53)
A	Country of origin: Germany	Country of origin
B	⏚	Symbol for the protective earth conductor, marks the protective earth connection of the M-660

3.4 Scope of Delivery

Item ID	Quantity	Components
M-660	1	Rotation stage according to order (p. 9)
000036450	1	M4 screw set for protective earth, consisting of: ▪ 1 M4x8 flat-head screw with cross recess, ISO 7045 ▪ 2 safety washers ▪ 2 flat washers
000029968	1	Screw set for fastening the M-660, consisting of: ▪ 5 M6x12 socket-head cap screws ISO 4762 ▪ 1 Allen wrench
MP121EK	1	Short instructions for PILine® stages
Additional scope of delivery for vacuum versions:		
C-815.VF	1	▪ Vacuum feedthrough, Sub-D 15 ▪ C815T0003 Technical Note for vacuum feedthrough
K030B0420	1	Extension cable for PILine®, MDR14 to Sub-D 15, 1.5 m

3.5 Suitable Controllers

Order Number	Description
C-867.160	Piezomotor controller / driver, networkable, 1 channel, for PILine® systems
C-867.260	Piezomotor controller with drive electronics, 2 channels, for PILine® systems
C-867.OE	OEM driver / controller card for PILine® ultrasonic motors, 1 channel

➢ To order, contact our customer service department (p. 39).

3.6 Accessories

Order Number	Description
M-663.AB	▪ Adapter box, MDR to 15-pin Sub-D, for PILine® stages with long cables ▪ M663T0015 Technical Note for adapter box
Extension cables for use with the M-663.AB adapter box:	
M-663.A01 M-663.A03 M-663.A05	Extension cable for PILine®, MDR to 15-pin Sub-D, 1 m Extension cable for PILine®, MDR to 15-pin Sub-D, 3 m Extension cable for PILine®, MDR to 15-pin Sub-D, 5 m Longer cables available on request.

➢ To order, contact our customer service department (p. 39).

3.7 Technical Features

3.7.1 Rotary Encoder

The M-660 is equipped with an optical rotary encoder. For the encoder resolution, refer to the table in the "Specifications" section (p. 41).

Optical rotary encoders measure the actual position directly (direct metrology). Therefore, errors occurring in the drivetrain, such as nonlinearity, backlash or elastic deformation, cannot influence the measurement of the position.

3.7.2 Reference Point Switch

The M-660 rotation stages have an optical reference point switch (see "Reference Point Switch Specifications", p. 42).

Used reference point switch type:

- M-660.45 and M-660.45V: No direction sensing
- M-660.55 and M-660.55V: Direction-sensing reference point switch

See the controller user manual and/or associated software manuals for the commands which make use of the reference point signal.

After a reference move of the M-660, the 0° mark on the moving platform is above the reference point switch.

4 Unpacking

INFORMATION

When handling the vacuum version of the rotation stage, attention must be paid to appropriate cleanliness. At PI, all parts are cleaned before assembly. During assembly and measurement, powder-free gloves are worn. Afterwards, the rotation stage is cleaned once again by wiping and shrink-wrapped twice in vacuum-compatible film.

- Only touch the rotation stage with powder-free gloves.
- If necessary, wipe the rotation stage clean after unpacking.

1. Unpack the M-660 with care.
2. Compare the contents against the items covered by the contract and against the packing list.
3. Inspect the contents for signs of damage. If parts are missing or you notice signs of damage, contact PI immediately.
4. Keep all packaging materials in case the product needs to be returned.

5 Installation

In this Chapter

General Notes on Installation 17
Connecting the M-660 to the Protective Earth Conductor 19
Mounting the M-660 on a Surface 21
Affixing the Load to the M-660 23
Connecting the Vacuum Version to the Controller 24
Connecting the Extension Cable 26

5.1 General Notes on Installation

CAUTION

Dangerous voltage and residual charge on piezo actuators!

Piezomotors are driven by piezo actuators. After being disconnected from the electronics, piezo actuators can stay electrically charged for several hours. Temperature changes can also induce charges in piezo actuators. Touching or short-circuiting the contacts in the connector of the M-660 can lead to minor injuries from electric shock.

➢ Do **not** touch the contacts in the connector of the M-660.

NOTICE

Lubricants, dirt, condensation!

Dirt, oil, lubricants and condensation will render the motor/drive inoperable.

➢ Ensure that the piezomotors of the M-660 do not come into contact with lubricants.

➢ Keep the M-660 free from dirt and condensation.

NOTICE

Heating up of the M-660 during operation!

The heat produced during operation of the M-660 can affect your application.

➢ Install the M-660 so that your application is not affected by the dissipating heat.

NOTICE

Unsuitable cables!

Unsuitable cables can cause damage to the controller and can affect the performance of the M-660.

- ➢ Only use original PI parts to connect the M-660 to the controller.
- ➢ If you need longer cables, use the M-663.AB adapter box and an extension cable from PI (p. 26).

NOTICE

Unintentional changes in position with vertical mounting!

If the load exceeds the maximum torque of the drive when the rotation stage is mounted vertically, unintentional changes in the position of the moving platform occur. Unintentional changes in position of the moving platform can damage the drive, the load or the environment.

- ➢ When a rotation stage is mounted vertically, make sure that the installed load is lower than the maximum torque of the drive (p. 41).

INFORMATION

For the reproducibility of the positioning to be optimal, all components must be affixed with zero-backlash.

- ➢ Make sure that rotation stage and load are affixed with zero-backlash.

- ➢ If possible, perform a simulation of the rotation stage motions with a mounted load or suitable calculations in order to identify collisions or unfavorable center of gravity constellations.
- ➢ If necessary, take suitable constructive measures to avoid collisions and instabilities in the overall system.
- ➢ Avoid or mark danger zones that result from the installation of the rotation stage and the application, in accordance with the legal regulations.

For more information about operational conditions, refer to the "Motor Power" section (p. 45).

5.2 Connecting the M-660 to the Protective Earth Conductor

INFORMATION

➢ Observe the applicable standards for mounting the protective earth conductor.

An M4 hole is located on the M-660 next to the cable exit, for connecting the protective earth conductor. In the following figure, this hole is marked with the symbol for the protective earth conductor ⏚.

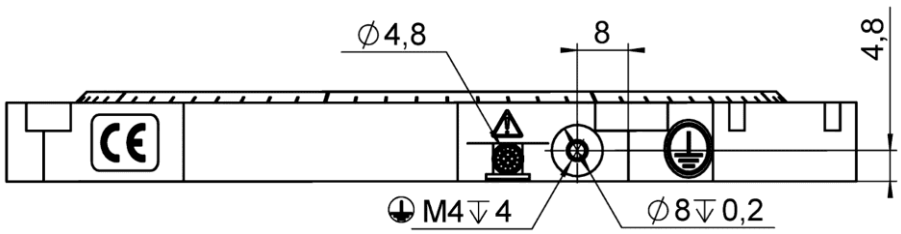

Figure 3: M4 threaded hole for mounting the protective earth conductor

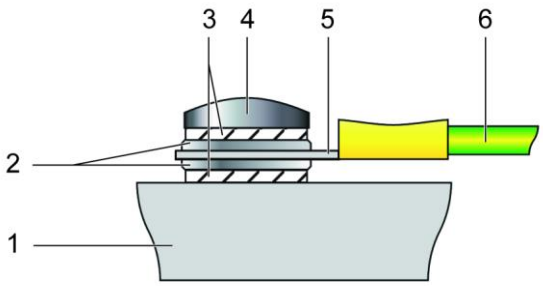

Figure 4: Mounting of the protective earth conductor (profile view)

1 Base body of the M-660
2 Flat washer
3 Safety washer
4 Screw
5 Cable lug
6 Protective earth conductor

Prerequisite

- ✓ You have read and understood the General Notes on Installation (p. 17).
- ✓ The M-660 is **not** connected to the controller.

Tools and accessories

- Suitable protective earth conductor: Cross-sectional area of the cable ≥0.75 mm^2
- Supplied M4 screw set for protective earth (p. 12) for mounting a protective earth conductor
- Suitable screwdriver

Connecting the M-660 to the protective earth conductor

1. If necessary, fasten a suitable cable lug to the protective earth conductor.
2. Fasten the cable lug of the protective earth conductor using the M4 screw on the protective earth connection of the M-660 as shown in the profile view.
3. Tighten the M4 screw with a torque of 1.2 Nm to 1.5 Nm.
4. Make sure that the contact resistance at all connection points relevant for mounting the protective earth conductor is <0.1 Ω at 25 A.

5.3 Mounting the M-660 on a Surface

NOTICE

Warping of the base body!

Incorrect mounting can warp the base body. Warping of the base body will increase wear and reduce accuracy.

- Mount the M-660 on an even surface. The recommended evenness of the surface is 10 µm.
- For applications with great temperature changes:
  Only fasten the M-660 to surfaces that have the same or similar thermal expansion properties as the M-660 (e.g. surfaces made of aluminum).

INFORMATION

The positive direction of motion is a clockwise rotation (turn to the right).

Figure 5: M-660: Counter-sunk holes in the base body (white arrows = 4 x M6, black arrows = 4 x M4)

Prerequisite

- ✓ You have read and understood the General Notes on Installation (p. 17).
- ✓ You have provided a suitable surface (for the required position and depth of the holes for accommodating the screws, see "Dimensions", p. 49).
  - Four M6 or M4 holes are present.
  - The evenness of the surface is ≤10 µm.
  - For applications with great temperature changes: The surface should have the same or similar thermal expansion properties as the M-660 (e.g. surface made of aluminum).
- ✓ You accounted for the space required for cable routing free of kinks and in accordance with regulations.
- ✓ The M-660 is **not** connected to the controller.

Tools and accessories

- Mounting accessories in the scope of delivery (p. 12):
  - 4 M6x12 screws
  - Allen wrench
- Alternative (not in the scope of delivery):
  - Four M4 screws of suitable length
  - Suitable screwdriver

Mounting the M-660 on a surface

1. Align the M-660 on the surface so that the selected holes in the M-660 (see arrows in the figure) overlap with the corresponding holes in the surface.
2. Introduce four suitable screws into the selected counter-sunk holes in the base body of the M-660.
3. Screw in the screws completely.
4. Check that the M-660 fits on the surface without backlash.

5.4 Affixing the Load to the M-660

NOTICE

Impermissibly high forces and torques!

Impermissibly high forces and torques that are applied to the moving platform can damage the M-660.

- For affixing type and mass of the load, observe the maximum permissible forces according to the specifications (p. 41).
- Avoid tilting torques >0.5Nm at the moving platform.

NOTICE

Screws that are too long!

The M-660 can be damaged by screws that are too long.

- Note the depth of the mounting holes in the moving platform (p. 49).
- Only use screws of the correct length for the respective mounting holes.

Figure 6: M-660, M3 holes for affixing a load (see arrows)

Prerequisite

- ✓ You have read and understood the General Notes on Installation (p. 17).
- ✓ You have properly mounted the M-660 on a surface (p. 21).
- ✓ The M-660 is **not** connected to the controller.
- ✓ You have prepared the load so that it can be affixed to the mounting holes on the moving platform:
  - The distance between the center of gravity of the load and the center of the moving platform is as small as possible in all directions.
  - At least three points are provided for affixing the load on the moving platform.

Tools and accessories

- At least three M3 screws of suitable length (p. 49)
- Suitable tools for fastening the screws

Affixing the load

1. Align the load on the M-660 so that the mounting holes in the load and the holes in the moving platform overlap.
2. Affix the load with at least three screws.
3. Check that the load fits on the moving platform of the M-660 without backlash.

5.5 Connecting the Vacuum Version to the Controller

For the vacuum version of the M-660, it is necessary to install a vacuum feedthrough (p. 12).

Prerequisites

- ✓ You have read and understood the General Notes on Installation (p. 17).
- ✓ The controller is **switched off**.
- ✓ You have connected the M-660 to the protective earth conductor (p. 19).
- ✓ You have read and understood the C815T0003 Technical Note for the C-815.VF vacuum feedthrough.

Tools and accessories

- C-815.VF vacuum feedthrough, Sub-D 15 (p. 12)
- K030B0420 extension cable for PILine®, MDR14 to Sub-D 15, 1.5 m, on the air side (p. 12)
- Suitable tools for installing the vacuum feedthrough

Installing the vacuum feedthrough

1. Find the dimensions of the vacuum feedthrough in the C815T0003 Technical Note (see "shell size 2").
2. Provide the vacuum chamber with a suitable opening.
3. Install the vacuum feedthrough so that the Sub-D 15 (f) socket is in the vacuum chamber.

Connecting the vacuum version to the controller

➢ Connect the M-660 ("stage"), vacuum feedthrough and controller as shown in the connection diagram below.

– Observe the assignment that is given by the labeling on the sockets, connectors and cables.

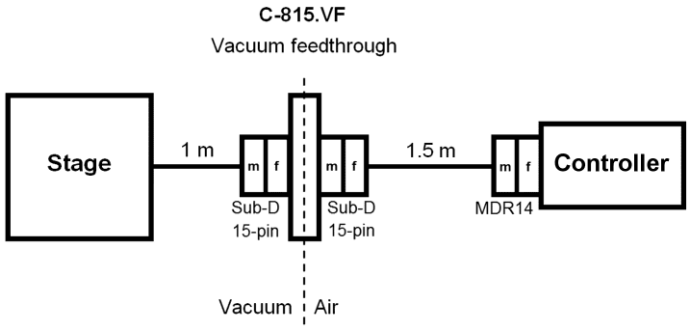

Figure 7: Connection of the vacuum version to the controller

5.6 Connecting the Extension Cable

Prerequisites

- ✓ You have read and understood the General Notes on Installation (p. 17).
- ✓ The controller is **switched off**.
- ✓ You have connected the M-660 to the protective earth conductor (p. 19).
- ✓ For vacuum versions:
  The C-815.VF vacuum feedthrough is installed (p. 24).

Tools and accessories

- M-663.AB adapter box*, MDR14 to Sub-D 15-pin, for PILine® stages with long cable
- Extension cable* for PILine®, MDR14 to Sub-D 15-pin, 1 to 5 m, on the air side

*Not in the scope of delivery; see "Accessories" (p. 13).

Connecting the extension cable

- ➢ Connect the M-660 ("stage") and controller via the adapter box and the extension cable as shown in the respective connection diagram.
  - – Observe the assignment that is given by the labeling on the sockets, connectors and cables.

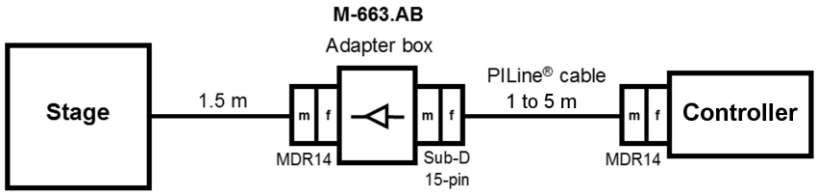

Figure 8: Connection of an extension cable to the standard version of the M-660

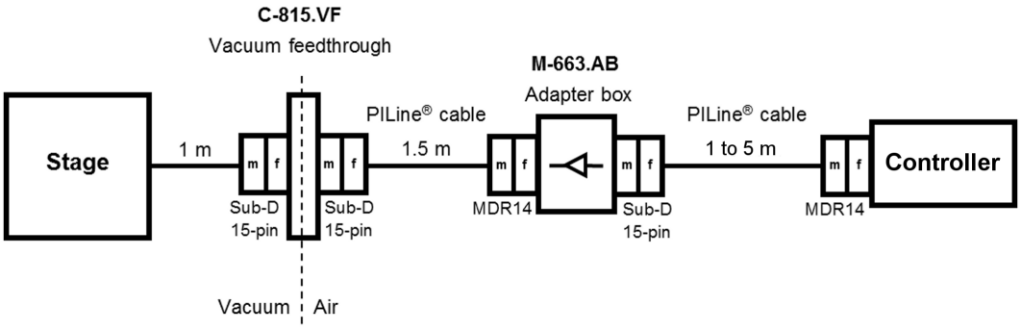

Figure 9: Connection of an extension cable to the vacuum version of the M-660

6 Start-Up and Operation

In this Chapter

General Notes on Start-Up and Operation 29
Starting Up the M-660 with the C-867 Controller 32

6.1 General Notes on Start-Up and Operation

CAUTION

Risk of electric shock if the protective earth conductor is not connected!

If a protective earth conductor is not or not properly connected, dangerous touch voltages can occur on the M-660 in the case of malfunction or failure of the system. If touch voltages exist, touching the M-660 can result in minor injuries from electric shock.

- Connect the M-660 to a protective earth conductor (p. 19) before start-up.
- Do **not** remove the protective earth conductor during operation.
- If the protective earth conductor has to be removed temporarily (e. g. in the case of modifications), reconnect the M-660 to the protective earth conductor before starting it up again.

NOTICE

Damage if an incorrect controller is connected!

Connecting a rotation stage to an unsuitable controller can cause damage to the rotation stage or controller.

- Only connect a rotation stage with PILine® ultrasonic piezomotors to a PILine® controller (p. 12).

NOTICE

Operating voltage too high or incorrectly connected!

Operating voltages that are too high or incorrectly connected can cause damage to the M-660.

- Only operate the M-660 with controllers/drivers and original accessories from PI.
- Do **not** exceed the operating voltage range (p. 42) for which the M-660 is specified.
- Only operate the M-660 when the operating voltage is properly connected; see "Pin Assignment" (p. 50).

NOTICE

Unintentional motions!

When the M-660 is being connected to the controller, it can carry out unintentional motions. Defective software or wrong operation of the software can also result in unintentional motions.

- Do not place any objects in areas where they can get caught by moving parts.
- Before connecting the M-660, check whether a macro is defined as the start-up macro in the controller, and cancel the selection of the start-up macro if necessary.

NOTICE

Damage from collisions!

Collisions can damage the rotation stage, the load to be moved and the environment.

- Make sure that no collisions are possible between the rotation stage, the load to be moved and the environment in the motion range of the rotation stage.
- Do not place any objects in areas where they can get caught by moving parts.
- Stop the motion immediately if a controller malfunction occurs.
- If possible, adapt the travel range limits of your mechanical system in the software that you use for commanding the motion.

NOTICE

Uncontrolled oscillation!

Your application can be damaged by uncontrolled oscillation of the M-660.
If you encounter noise during operation:

- ➢ Immediately switch off the servo-control system of the affected axes.
- ➢ Check the settings of the servo-control parameters.

NOTICE

Overheating during continuous operation!

The highest dynamic force and holding force are achieved at maximum motor power; however, the M-660 may overheat during continuous operation.

- ➢ Observe the recommended motor power depending on the duty cycle and the ambient temperature (p. 47).

NOTICE

Damage or considerable wear from high accelerations!

High accelerations can cause damage to or considerable wear on the mechanical system.

- ➢ Stop the motion immediately if a controller malfunction occurs.
- ➢ Determine the maximum velocity for your application.
- ➢ Observe the information in the "Motor Power" section (p. 45).

INFORMATION

Although in theory the M-660 operates quietly, noise levels of up to 50 dB (A) are possible during operation. The ultrasonic drive of the M-660 can also generate higher noise levels at frequencies between 100 and 500 kHz.

INFORMATION

The positive direction of motion is a clockwise rotation (turn to the right).

INFORMATION

The repeatability of the positioning is only ensured when the reference point switch is always approached from the same side. Controllers from PI fulfill this requirement as a result of the automatic direction sensing for reference moves to the reference switch.

INFORMATION

For maximum force generation, a run-in procedure is necessary during the start-up of the M-660 and after longer downtimes; see also "Influence of Downtimes on the Torque" (p. 48). After run-in, the M-660 will generate its maximum dynamic force.

- For run-in, command a few motion cycles at low velocity. The motion cycles should comprise full revolutions if possible.

For more information about operational conditions, refer to the "Motor Power" section (p. 45).

6.2 Starting Up the M-660 with the C-867 Controller

NOTICE

Incorrect parameter settings!

When using the software which is included in the scope of delivery of the C-867 controller, the operating parameters of the M-660 can be loaded from a stage database. The stage *PIStages2.dat* database contains the default parameter values of your rotation stage for performing initial test motions during start-up. Depending on the application, using the default parameter values (e. g. for P-term, I-term, D-term, acceleration and velocity) can, however, cause damage to the rotation stage, especially when operated with heavy loads.

- If possible: Perform the first start-up without a load.
- Always install the latest version of the *PIStages2.dat* stage database on your PC.

For start-up with a load:

- Before start-up, make sure that the M-660 has been properly installed (p. 17).
- For optimum performance of the moving axis, adjust the operating parameters of the C-867 (e. g. P-term, I-term, D-term, acceleration, velocity; see C-867 User Manual).
- Save the new parameter values for future use in a stage database on the PC or in the non-volatile memory of the controller (see C-867 User Manual and PIMikroMove User Manual).

Prerequisites

- ✓ You have read and understood the General Notes on Start-Up and Operation (p. 29).
- ✓ You have read and understood the user manual of the C-867 piezomotor controller/driver.
- ✓ In the case of start-up with a load: The M-660 has been properly installed (p. 17).
- ✓ The C-867 piezomotor controller/driver and the required software have been installed. All connections on the C-867 have been established (see C-867 User Manual).

Starting up the M-660 with the C-867 controller

- ➢ Start up the axis (see C-867 User Manual).
  The start-up involves the following steps:
  - Selecting the stage type
  - Defining the reference point of the axis
  - Commanding initial motions in closed-loop operation for testing and for run-in of the mechanical system

  The description in the C-867 User Manual assumes that you perform these steps using PIMikroMove.

7 Maintenance

In this Chapter

General Notes on Maintenance 35
Performing a Maintenance Run 35
Cleaning the M-660 36

7.1 General Notes on Maintenance

NOTICE

Damage due to improper maintenance!

Improper maintenance can result in the failure of the M-660.

- Only loosen screws according to the instructions in this manual.
- Ensure that the piezomotors of the M-660 do not come into contact with lubricants.

7.2 Performing a Maintenance Run

Depending on the operating conditions and the period of use of the M-660, the following maintenance measures are required:

Maintenance run

The maintenance run is performed to redistribute the existing lubricant on the bearings of the M-660. The stage must rotate at least one full turn during the maintenance run.

- To evenly distribute the existing lubricant on the stage bearings, perform a maintenance run after 500 hours of operation or after 1 year at the latest.
- If you move your M-660 over a small working range (<20°) in continuous industrial operation, perform a maintenance run after every 5000 motion cycles.

Lubrication

Under laboratory conditions, the bearings of the M-660 only need to be lubricated in exceptional cases. For continuous industrial use, the lubrication intervals must be defined individually.

- Do not lubricate the bearings of the M-660 without consulting our customer service department (p. 39).
- To lubricate the bearings, follow the instructions given in the maintenance manual which you can obtain from our customer service department.
- Ensure that the piezomotors of the M-660 do not come into contact with lubricants.

7.3 Cleaning the M-660

Prerequisites

- ✓ You have disconnected the rotation stage from the controller.

Cleaning the rotation stage

- Do **not** use any organic solvents.

Only when the rotation stage is **not** used in vacuum:

- When necessary, clean the surfaces of the rotation stage with a cloth slightly dampened with a mild cleanser or disinfectant.

Only when the rotation stage is used in vacuum:

- Only touch the rotation stage with powder-free gloves.
- If necessary, wipe the rotation stage clean.

8 Troubleshooting

Problem	Possible Causes	Solution
Noise during operation	Uncontrolled oscillation of the M-660	➢ Immediately switch off the servo-control system of the affected axes. ➢ Check the settings of the servo-control parameters.
rotation stage positions inaccurately	Settling window around the target position is too large	➢ Reduce the settling window by changing the parameter values for the settling window limits on the controller. See the controller user manual (p. 3) for details.
Reaching the target position takes too long	Settling window around the target position is too small	➢ Enlarge the settling window by changing the parameter values for the settling window limits on the controller. See the controller user manual (p. 3) for details.
Increased wear Reduced accuracy	Warped base body	➢ Mount the M-660 on an even surface. The recommended evenness of the surface is 10 µm. ➢ For applications with great temperature changes: Only mount the M-660 on surfaces that have the same or similar thermal expansion properties as the M-660 (e.g. surfaces made of aluminum).
No or limited motion	Excessive load	➢ Reduce the load (see "Data Table", p. 41). ➢ When a rotation stage is mounted vertically, make sure that the installed load is lower than the maximum torque of the drive (p. 41).

If the problem that occurred with your system is not listed in the table above or cannot be solved as described, contact our customer service department (p. 39).

9 Customer Service

For inquiries and orders, contact your PI sales engineer or send us an e-mail (info@pi.ws).

If you have questions concerning your system, have the following information ready:

- Product codes and serial numbers of all products in the system
- Firmware version of the controller (if present)
- Version of the driver or the software (if present)
- Operating system on the PC (if present)

The latest versions of the user manuals are available for download (p. 3) on our website.

10 Technical Data

In this Chapter

Specifications 41
Ambient Conditions and Classifications 44
Motor Power 45
Dimensions 49
Pin Assignment 50

10.1 Specifications

10.1.1 Data Table

	M-660.45	M-660.55	Unit	Tolerance
Active axes	θ_Z	θ_Z		
Motion and positioning				
Rotation range	No limit	No limit	°	
Integrated sensor	Incremental encoder	Incremental encoder		
Design resolution	4 (0.00023)	34 (0.00195)	µrad (°)	typ.
Min. incremental motion	12	34	µrad	typ.
Bidirectional repeatability	±24	±68	µrad	
Velocity	720	720	°/s	max.
Mechanical properties				
Load capacity / axial force	20	20	N	max.
Holding force	0.3	0.3	Nm	max.
Torque cw / ccw (θ_Z)	0.3	0.3	Nm	max.
Drive properties				
Motor type	U-164 PILine® ultrasonic piezomotor	U-164 PILine® ultrasonic piezomotor		
Reference point switch	Optical	Optical		
Miscellaneous				
Operating temperature range	-20 to 50	-20 to 50	°C	
Material	Al (black anodized)	Al (black anodized)		
Mass	470	470	g	±5 %

Cable length	1.5	1.5	m	±10 mm
Connector	MDR, 14-pin	MDR, 14-pin		
Recommended controller/driver	C-867 PILine® Motion Controller	C-867 PILine® Motion Controller		

The specifications for vacuum versions (p. 9) can differ. Ask about custom designs!

10.1.2 Reference Point Switch Specifications

Type	Optical sensor
Supply voltage	+5 V/GND, supply via the motor connector
Signal output	TTL level

10.1.3 Maximum Ratings

M-660 rotation stages are designed for the following operating data:

Device	**Maximum Operating Voltage**	**Operating Frequency**	**Maximum Power Consumption**
M-660.45 M-660.45V M-660.55 M-660.55V	200 V_{pp} or 71 V_{rms}	152 to 165 kHz	30 W

10.1.4 Specifications for Vacuum-Compatible Versions

The following vacuum-compatible components are used for the M-660.45V and M-660.55V:

Component	Material
Mechanical parts	Aluminum (blank), aluminum (anodized, black, matt), steel, ceramic (PIC181, Al_2O_3), PEEK, PTFE
Cables	FEP; ribbon cable (FFC) from Axon Kabel GmbH
Shrink tubing	PVDF (Kynar)
Connector	Sub-D 15 (m)
Insulation	KU-THE-150
Lubricant	Molykote HP-300
Sealant	Scotch Weld
Adhesives	Epoxy resin-based adhesive

Bakeout temperature: 80°C (176°F)

Bakeout time: 3 hours

10.2 Ambient Conditions and Classifications

The following ambient conditions and classifications must be observed for the M-660:

Area of application	For indoor use only
Maximum altitude	2000 m
Air pressure	1100 hPa to 0.1 hPa (corresponds to roughly 825 torr to 0.075 torr)
Relative humidity	Highest relative humidity 80 % for temperatures up to 31 °C Decreasing linearly to 50 % relative humidity at 40 °C
Operating temperature	-20 °C to 50 °C
Storage temperature	-20 °C to 75 °C
Transport temperature	-20 °C to 75 °C
Overvoltage category	II
Protection class	I
Degree of pollution	1
Degree of protection according to IEC 60529	IP20

10.3 Motor Power

10.3.1 Motor Power and Operating Voltage

The following table shows the relationship between the operating voltage and the motor power of the M-660. The operating voltage is output by the C-867 controller and depends on the actual control value. The polarity sign of the control value determines the direction of motion.

Motor Power	Operating Voltage	Corresponding Control Value on the C-867*
0 %	0 V_{pp}	0
25 %	50 V_{pp}	8192 or -8192
50 %	100 V_{pp}	16384 or -16384
75 %	150 V_{pp}	24575 or -24575
100 %	200 V_{pp}	32767 or -32767

* Generated in closed-loop operation via the control algorithm or set in open-loop operation via the `SMO` command

INFORMATION

The control value and thus the output operating voltage are limited by the C-867 controller with the ***Maximum Motor Output*** parameter (ID 0x9). When you load the operating parameters of the M-660 from the *PIStages2.dat* stage database, this parameter is set to a suitable value.

You can check the control value of the C-867 as follows:

- Get the current control value with the `SMO?` command.
- Record the control value during the motion with the data recorder (as "motor output").

For further information, see the user manual of the controller (p. 12) used to operate the M-660.

10.3.2 Velocity and Torque

The following figure can be used to estimate the velocity and torque of the M-660 with different motor powers.

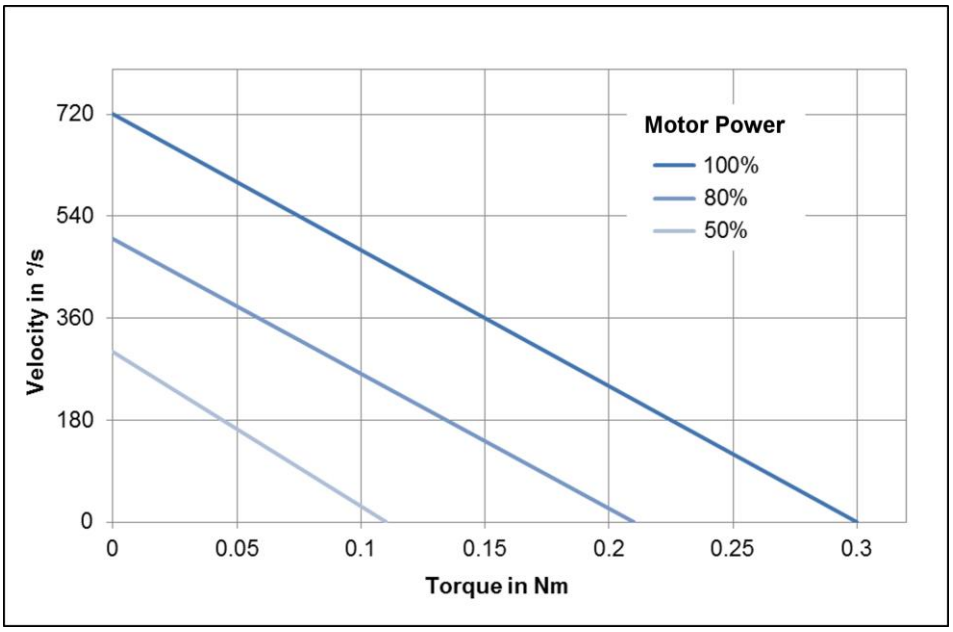

Figure 10: Relationship between velocity and torque of the M-660 with different motor powers

10.3.3 Motor Power and Lifetime

Motor power, duty cycle and ambient temperature influence the lifetime of the stage. In order to prevent overheating and high wear, the motor power and the duty cycle should not exceed the limits given in the following graph in continuous operation. A load cycle corresponds to a positioning run and includes the acceleration, motion, deceleration as well as downtime (break). The motor should only sporadically be operated at peak power; the peak power serves as a control reserve.

INFORMATION

In a vacuum, there is no heat dissipation via convection.

- Operate the vacuum version of the M-660 with a 20% lower motor power than given in the graph, or reduce the duty cycle.

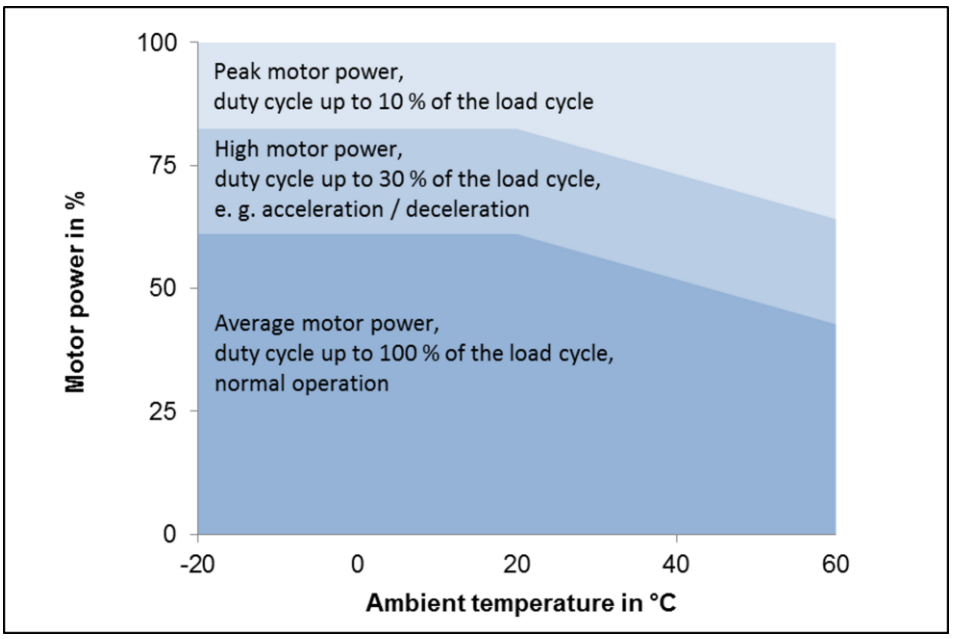

Figure 11: M-660: Recommended duty cycle and motor power depending on the ambient temperature

10.3.4 Influence of Downtimes on the Torque

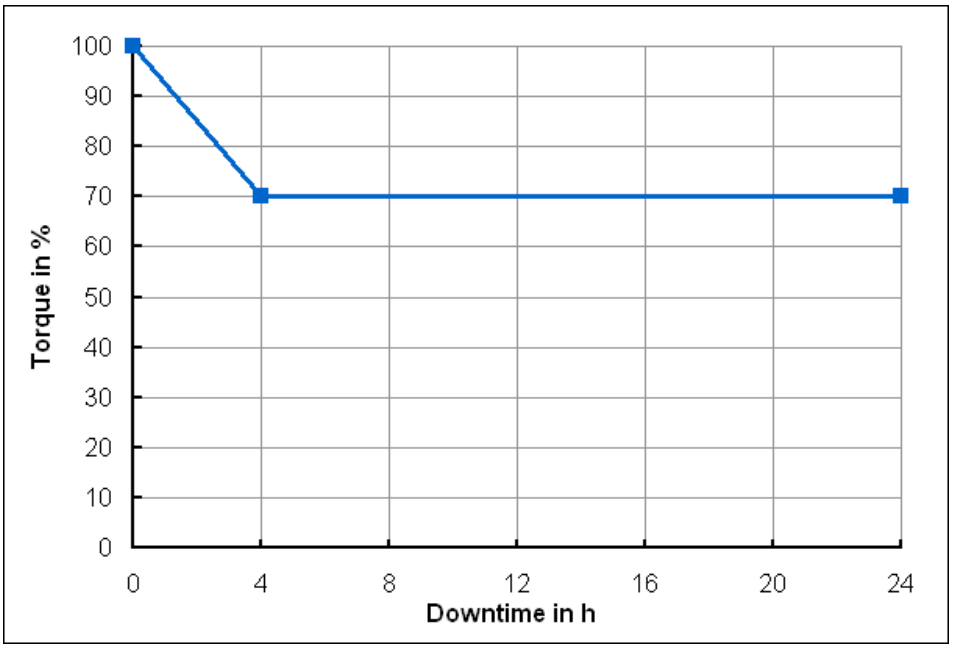

Figure 12: Torque of the M-660 depending on the downtime of the motor

10.4 Dimensions

Dimensions in mm. Note that the decimal places are separated by commas in the drawings.

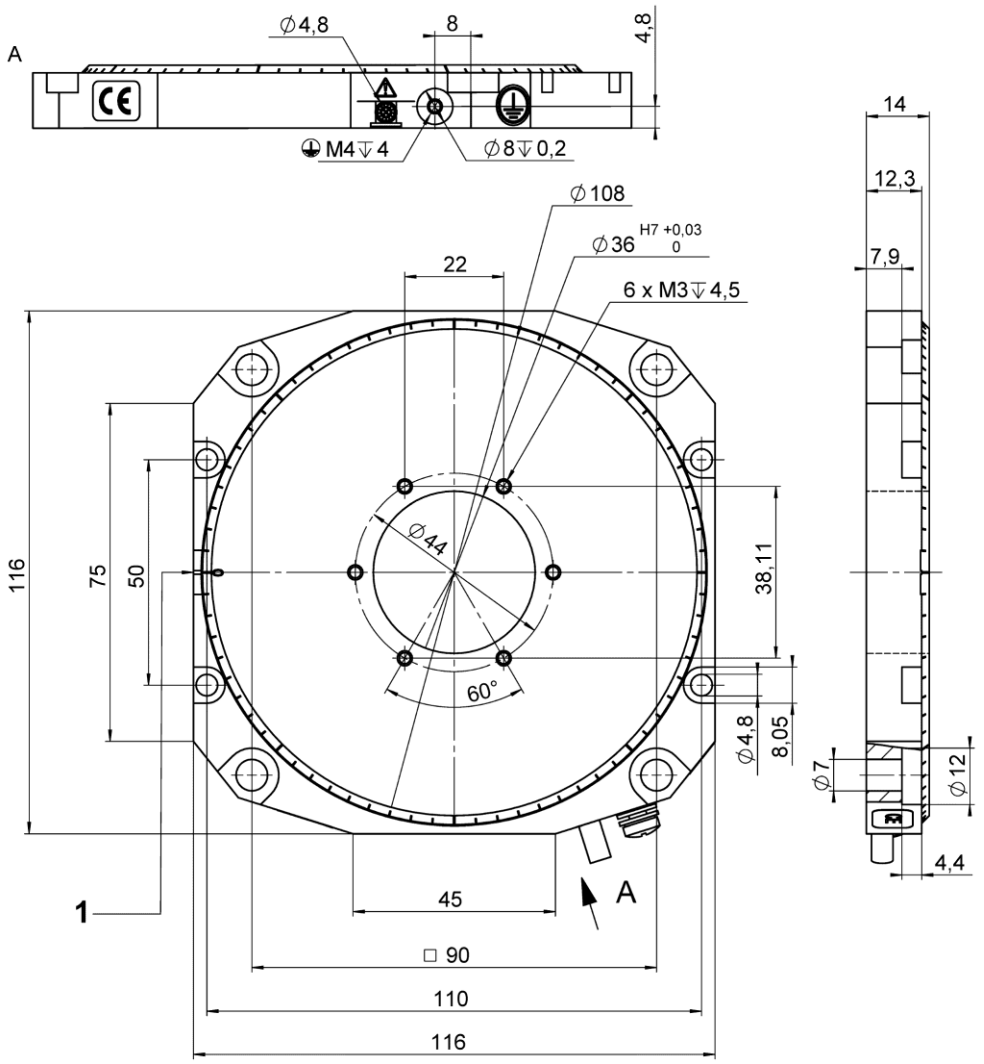

Figure 13: M-660.45 and M-660.55; [1]: Position of the 0° mark after the reference point definition

10.5 Pin Assignment

Connector: MDR14, N10214-52B2VC (3M)

Not for vacuum versions.

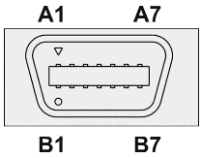

Figure 14: Front view of the MDR14 connector

Pin	Signal	Function
A1	GND	0 V
A2	NC	Not connected
A3	NC	Not connected
A4	REFSWITCH	Output: Reference point switch
A5	NC	Not connected
A6	VDD	Input: +5 V
A7	USM_P1	Input: Piezo 71 VAC (RMS)
B1	USM_P2	Input: Piezo 71 VAC (RMS)
B2	USM_P3	Input: Piezo 71 VAC (RMS)
B3	ENCA+	Output: Encoder channel A, RS-422
B4	ENCA-	Output: Encoder channel A (inverted), RS-422
B5	ENCB+	Output: Encoder channel B, RS-422
B6	ENCB-	Output: Encoder channel B (inverted), RS-422
B7	NC	Not connected

Connector: Sub-D 15 (m)

Only for vacuum versions.

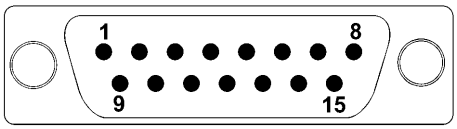

Figure 15: Front view of the Sub-D 15 connector

Pin	Signal	Function
1	NC	Not connected
2	USM_P1	Input: Piezo 71 VAC (RMS)
3	USM_P2	Input: Piezo 71 VAC (RMS)
4	VDD	Input: +5 V
5	NC	Not connected
6	GND	0 V
7	ENCA-	Output: Encoder channel A (inverted), RS-422
8	ENCB-	Output: Encoder channel B (inverted), RS-422
9	NC	Not connected
10	GND	0 V
11	USM_P3	Input: Piezo 71 VAC (RMS)
12	NC	Not connected
13	REFSWITCH	Output: Reference point switch
14	ENCA+	Output: Encoder channel A, RS-422
15	ENCB+	Output: Encoder channel B, RS-422

11 Old Equipment Disposal

In accordance with the applicable EU law, electrical and electronic equipment may not be disposed of with unsorted municipal wastes in the member states of the EU.

When disposing of your old equipment, observe the international, national and local rules and regulations.

To meet the manufacturer's product responsibility with regard to this product, Physik Instrumente (PI) GmbH & Co. KG ensures environmentally correct disposal of old PI equipment that was first put into circulation after 13 August 2005, free of charge.

If you have old PI equipment, you can send it postage-free to the following address:

Physik Instrumente (PI) GmbH & Co. KG

Auf der Römerstr. 1

D-76228 Karlsruhe, Germany

12 Declaration of Conformity

PI

Declaration of Conformity

according to DIN EN ISO/IEC 17050-1:2005

Manufacturer: **Physik Instrumente (PI) GmbH & Co. KG**

Manufacturer's Address: Auf der Roemerstrasse 1
D-76228 Karlsruhe,
Germany

CE

The manufacturer hereby declares that the product

Product Name: **PILine® Rotation Stage**

Model Numbers: **M-660**

Product Options: **all**

complies with all relevant provisions of the **Machinery Directive (2006/42/EC)**.
Furthermore, it complies with all provisions of the **EMC Directive (2004/108/EC)** as well as the **RoHS Directive (2011/65/EC)**.

The applied standards certifying the conformity are listed below.

Safety of Machinery: EN 12100:2010

Electrical Safety: EN 61010-1:2010

Electromagnetic Emission: EN 61000-6-3:2007, EN 55011:2009

Electromagnetic Immunity: EN 61000-6-1:2007

The person authorized to compile the technical file is: Marc Thelen
Address: see manufacturer's address

November 29, 2012
Karlsruhe, Germany

Norbert Ludwig
Managing Director

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